NACA

RESEARCH MEMORANDUM

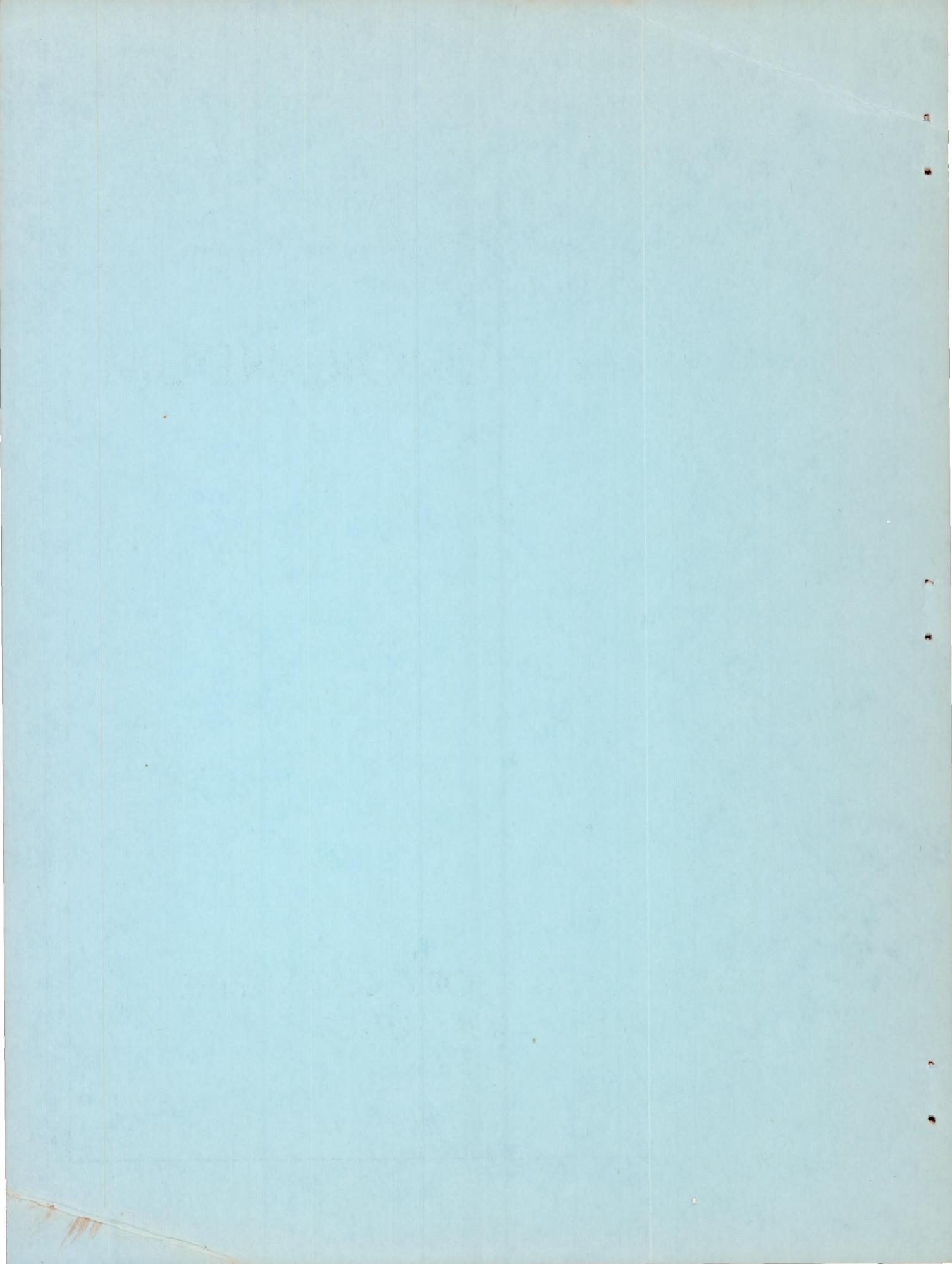EFFECTS OF AN ALL-MOVABLE

WING-TIP CONTROL ON THE LONGITUDINAL STABILITY OF A

60° SWEPTBACK-WING—INDENTED-BODY CONFIGURATION

EQUIPPED WITH FENCES AT TRANSONIC SPEEDS

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NATIONAL ADVISORY COMMITTEE
FOR AERONAUTICS
WASHINGTON

April 4, 1955
Declassified February 10, 1959

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SUMMARY

An investigation has been made to obtain the effects of a 20-percent-semispan all-movable wing-tip control (which was deflected -5° and -10°) on the longitudinal stability characteristics of a twisted and cambered 60° sweptback-wing—indented-body configuration equipped with fences at angles of attack which generally varied from 0° to 16° and over the Mach number range of 0.80 to 1.13. The Reynolds number based on the mean aerodynamic chord varied from 2.01×10^6 to 2.22×10^6.

Increased negative (trailing edge up) control deflection caused the pitching-moment curves to shift in a positive direction but had little effect on the lift coefficient for which the unstable break in the moment curves occurred. The longitudinal-control effectiveness remained constant at a value of 0.00435 throughout the test Mach number range. For the control deflections tested, the maximum lift coefficient for which the configuration could be trimmed below the unstable break in the pitching-moment curves decreased from approximately 0.55 at a Mach number of 0.80 to 0.26 at a Mach number of 1.13.

INTRODUCTION

Investigations of all-movable wing-tip controls (refs. 1 and 2) on wings of varied sweep have indicated that such a device would be effective for longitudinal control. It has also been shown in reference 3 that improvements in longitudinal stability can be obtained by negative (trailing edge up) deflection of all-movable wing-tip controls. On the basis of these investigations, an all-movable wing-tip control appeared

to be a suitable means of longitudinal control for a 60° sweptback-wing—
indented-body configuration which had been tested previously (ref. 4).

An investigation, therefore, has been conducted in the Langley 8-foot
transonic tunnel of the effectiveness of a 20-percent-semispan wing-tip
control on the same wing-body configuration of reference 4. The configu-
ration of reference 4 exhibited undesirable longitudinal stability char-
acteristics at moderate lift coefficients which were improved by the
addition of fences (ref. 5). The configuration of the present investi-
gation was equipped with the same fences reported in reference 5.

The data reported herein were obtained for several negative (trailing
edge up) control deflections over a Mach number range of 0.80 to 1.13 and
an angle-of-attack range which generally varied from 0° to 16°. The
Reynolds number based on the mean aerodynamic chord varied from 2.01×10^6
to 2.22×10^6.

COEFFICIENTS AND SYMBOLS

The test data are presented as standard NACA coefficients of forces
and moments. The data are referred to a set of axes coinciding with the
wind axes, the origin of which was located on the body axis at the same
longitudinal position as the quarter-chord of the wing mean aerodynamic
chord.

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient, Pitching moment/$qS\bar{c}$

L/D   lift-drag ratio

q   free-stream dynamic pressure, lb/sq ft

$\bar{c}$ mean aerodynamic chord, in.

S   wing area, sq ft

b/2   wing semispan, in.

M   free-stream Mach number

α   angle of attack of body axis, deg

δ angle of deflection of wing-tip control, positive when trailing edge is down, deg

C_{m_δ} rate of change of pitching-moment coefficient with wing-tip control deflection per deg (α is constant)

$C_{m_{C_L}}$ rate of change of pitching-moment coefficient with lift coefficient (δ is constant)

APPARATUS AND METHODS

Tunnel

The tests were conducted in the Langley 8-foot transonic tunnel which is a single-return wind tunnel having a dodecagonal, slotted test section. The use of longitudinal slots allows testing through the speed of sound with negligible effects of choking and blockage. The tunnel operates at atmospheric stagnation pressures.

Configurations

The configuration used in this investigation had a wing with 60° sweepback of the quarter-chord line, an aspect ratio of 4, and a taper ratio of 0.333. The wing was twisted and cambered to approximate a uniform load at a lift coefficient of 0.25 and a Mach number of 1.4. The wing was constructed of steel with a thickness distribution which varied from 12 percent at the root to 6 percent at 50 percent of the semispan and remained constant at 6 percent to the tip (fig. 1). NACA 64A-series airfoil sections were employed. The body was indented for a Mach number of 1.4 according to a supersonic area rule. This concept, along with more details of the wing and the coordinates for the wing and body, has been presented in reference 4.

The wings had full-chord upper-surface fences at 50 percent and 75 percent of the wing semispan on each wing panel. Details of the fences have been presented in reference 5. The wing-tip controls comprised the outboard 20 percent of each wing semispan and were deflected about a hinge axis normal to the plane of symmetry at 65 percent of the wing chord at the 80-percent-semispan station. A chordwise gap of 0.01 inch existed between the control surface and the wing. The area of the controls was equivalent to 10.4 percent of the wing area which was one square foot. Inasmuch as the wing was twisted and cambered, control deflections were measured with reference to the 87.5-percent-semispan station, which was twisted approximately -5° with respect to the fuselage center line

(fig. 1). Control deflections of 0°, -5°, and -10° when referred to the
fuselage center line would be approximately -5°, -10°, and -15°, respec-
tively. A photograph of the configuration with -10° wing-tip control
deflection is shown as figure 2. A drawing of the configuration is pre-
sented in figure 3. For the 0° control deflection a steel insert was
placed in the wing leading edge to prevent changes in control setting
due to control loading. For control deflections of -5° and -10°, the
control was held securely in place by a soldered metal strip (fig. 3).
Although aeroelastic effects on control lift and pitching-moment effec-
tiveness may tend to be adverse for this type of control, the results of
reference 6 indicate that for these tests the effects would be small.

Tests

The model was attached to a sting-support system by means of a three-
component electrical strain-gage balance. Control deflections of 0°, -5°,
and -10° were tested over the Mach number range of 0.80 to 1.13. The
angle of attack was measured by a pendulum-type inclinometer and generally
varied from 0° to 16° but in some cases was as high as 18°. The Reynolds
number based on a mean aerodynamic chord of 6.5 inches varied from
2.01×10^6 to 2.22×10^6.

Corrections and Accuracy

The drag data for these tests have been adjusted to the condition of
free-stream static pressure at the base of the model. No corrections
have been made for the interference effects of the sting-support system.
The accuracy of the lift, drag, and pitching-moment coefficients based on
balance design and repeatability of the data was ± 0.003, ± 0.001, and ± 0.003,
respectively. The accuracy of the measured angle of attack is believed to
be $\pm 0.10^{\circ}$, and the accuracy of the control deflections was $\pm 0.15^{\circ}$. The
local deviations of the free-stream Mach number in the region of the model
were no larger than 0.003 at subsonic speeds; with increases in speed, the
deviations increased but did not exceed 0.010 at a Mach number of 1.13.
The data presented are essentially free of boundary-reflected disturbances.
However, at a Mach number of 1.13, a reflected disturbance crossed the
tips of each wing so that approximately one third of the area of the tip
control was affected. It is believed that the effects of this disturbance
would be felt mainly on the pitching-moment and drag results. An exami-
nation of the results for the Mach number of 1.13 indicates no noticeable
effects on the pitching moment; however, the drag results appear to be
affected. No corrections have been applied to the drag results for the
effects of this disturbance.

RESULTS AND DISCUSSION

The longitudinal aerodynamic characteristics of the 60° sweptback-wing—indented-body configuration with the wing-tip controls deflected 0°, -5°, and -10° are presented in figure 4 for the various test Mach numbers. The effects of control deflection on the longitudinal stability of the model are presented in figure 5, and the variation of control pitching-moment effectiveness with Mach number is presented in figure 6. Although the configuration tested does not represent a complete configuration, the trimmed and untrimmed drag coefficients and lift-drag ratios will be presented, in subsequent figures, to indicate, qualitatively, some effects of trimming the configuration with a wing-tip control.

Effects on longitudinal stability and control.- Increasing the negative tip-control deflection shifted the pitching-moment curves in a positive direction (fig. 4(c)). The variation of the slope of the pitching-moment curves $C_{m_{C_L}}$, averaged in the lift-coefficient range of 0 to 0.25 for the three control deflections tested (fig. 5), shows that, for the Mach number range tested, increased negative control deflection generally resulted in increased stability.

Deflecting the wing-tip control had only small effects on the unstable break in the pitching-moment curve, which occurred at a lift coefficient slightly below 0.60 for the 0° control deflection. In general, deflecting the tip -5° slightly increased the lift coefficient at which the unstable break occurred, whereas increasing the deflection to -10° decreased the lift coefficient for the unstable break (see fig. 4(c)).

The variation of the longitudinal-control effectiveness parameter C_{m_δ} with Mach number, averaged at constant angles of attack over the lift-coefficient range of 0 to 0.25 (fig. 6), shows that the effectiveness of the tip controls remained constant at a value of 0.00435 throughout the Mach number range tested. The value $C_{m_\delta} = 0.00435$ is of the same order of magnitude as that obtained in reference 1 over a similar Mach number range for a tip control with either a triangular or a trapezoidal plan form on a wing with a 51.3° sweptback leading edge.

The maximum lift coefficient, for which this configuration could be trimmed below the unstable break in the pitching-moment curves, decreased for the control deflections tested from a value of 0.55 at a Mach number of 0.80 to 0.26 at a Mach number of 1.13. The out-of-trim pitching moments, however, for this configuration were generally small and, for a selected trim condition of 35,000 foot altitude and a wing loading of 100 pounds per square foot, the wing-tip control deflections required to

trim this configuration over the Mach number range of 0.80 to 1.13 would be of the order of those tested (-5° and -10°) (fig. 7). For any altitude below 35,000 feet, or any wing loading less than 100 pounds per square foot, the control deflections required would naturally be less.

Effect on drag coefficient.- Deflecting the tip controls negatively increased the drag at all Mach numbers for the range of lift coefficients tested (fig. 4(b)). The increase in mimimum drag for $\delta = -10°$ was more than twice as great as for $\delta = -5°$, and the lift coefficient at which this minimum drag occurred increased with increasing control deflection.

The trimmed and untrimmed drag of this configuration for the selected trim condition is presented in figure 8. The drag due to trim remained constant up to a Mach number of 0.95; above this value the drag increased slightly. The drag due to trim (represented in fig. 8 by the region between the two curves) represents a small part of the total trimmed drag and reflects the low out-of-trim pitching-moment values noted previously.

Effect on lift-drag ratio.- Trimming this configuration with wing-tip controls reduced the maximum untrimmed lift-drag ratio by approximately 9 percent at a Mach number of 1.0 and 20 percent at a Mach number of 1.13 (fig. 9). For the specific trim conditions of 35,000 foot altitude and a wing loading of 100 pounds per square foot, the trimmed lift-drag ratios closely approximate the maximum trimmed lift-drag ratios in the Mach number range of 0.90 to 1.13.

CONCLUSIONS

Results of an investigation over the Mach number range of 0.80 to 1.13 of the effects of a 20-percent-semispan wing-tip control (which was deflected -5° and -10°) on the longitudinal stability of a twisted and cambered 60° sweptback-wing—indented-body configuration equipped with fences at angles of attack which generally varied from 0° to 16° and over the Reynolds number range of 2.01×10^6 to 2.22×10^6 indicate the following:

1. Increased negative control deflection (trailing edge up) shifted the pitching-moment curves positively but had little effect on the lift coefficient for which the unstable break occurred in the pitching-moment curve.

2. The longitudinal-control effectiveness parameter C_{m_δ} remained constant with Mach number at a value of 0.00435.

3. The maximum lift coefficient for the control deflections tested, for which the configuration could be trimmed below the unstable break in the pitching-moment curve, decreased from 0.55 at a Mach number of 0.80 to 0.26 at a Mach number of 1.13.

Langley Aeronautical Laboratory,
    National Advisory Committee for Aeronautics,
        Langley Field, Va., December 20, 1954.

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1. Moseley, William C., Jr., and Watson, James M.: Investigation of Wing-Tip Ailerons on a 51.3° Sweptback Wing at Transonic Speeds by the Transonic-Bump Method. NACA RM L51H27, 1951.

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5. Fischetti, Thomas L.: Effects of Fences, Leading-Edge Chord-Extensions, Boundary-Layer Ramps, and Trailing-Edge Flaps on the Longitudinal Stability of a Twisted and Cambered 60° Sweptback-Wing—Indented-Body Configuration at Transonic Speeds. NACA RM L54D09a, 1954.

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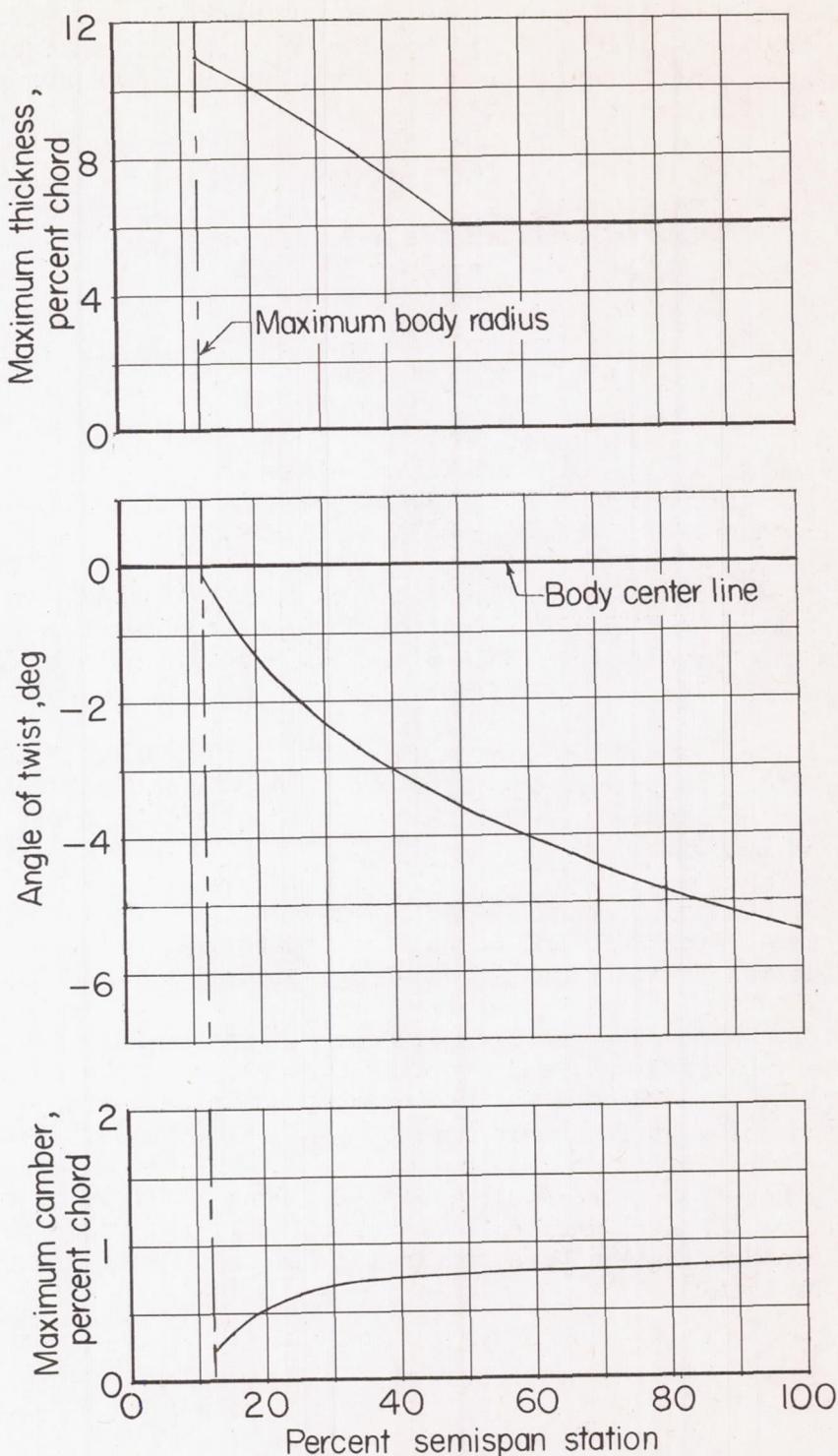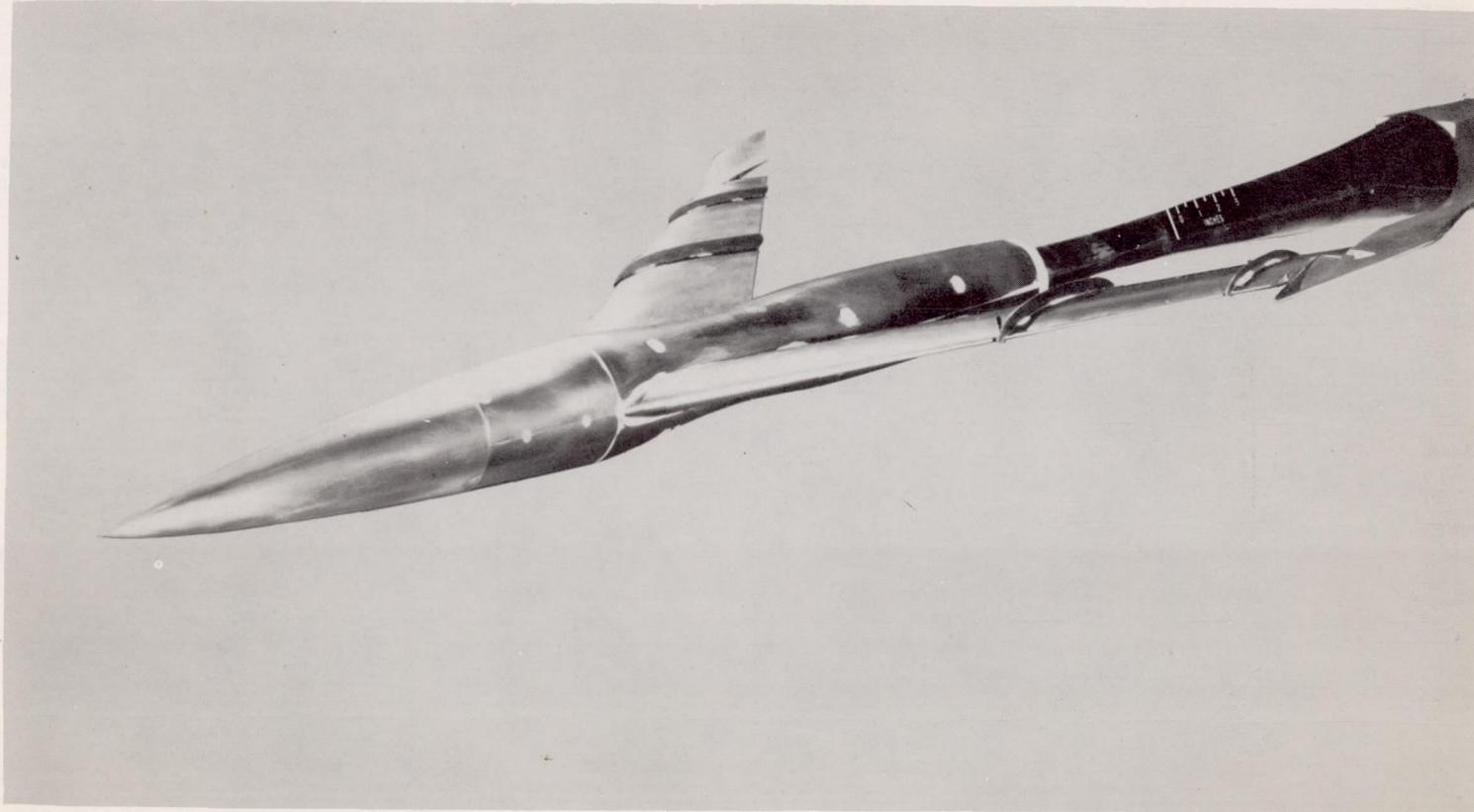
Figure 1.- Spanwise distribution of section thickness ratio, angle of twist, and maximum camber for sweptback-wing—indented-body configuration.

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Figure 2.- Sweptback-wing—indented-body configuration with 20-percent-
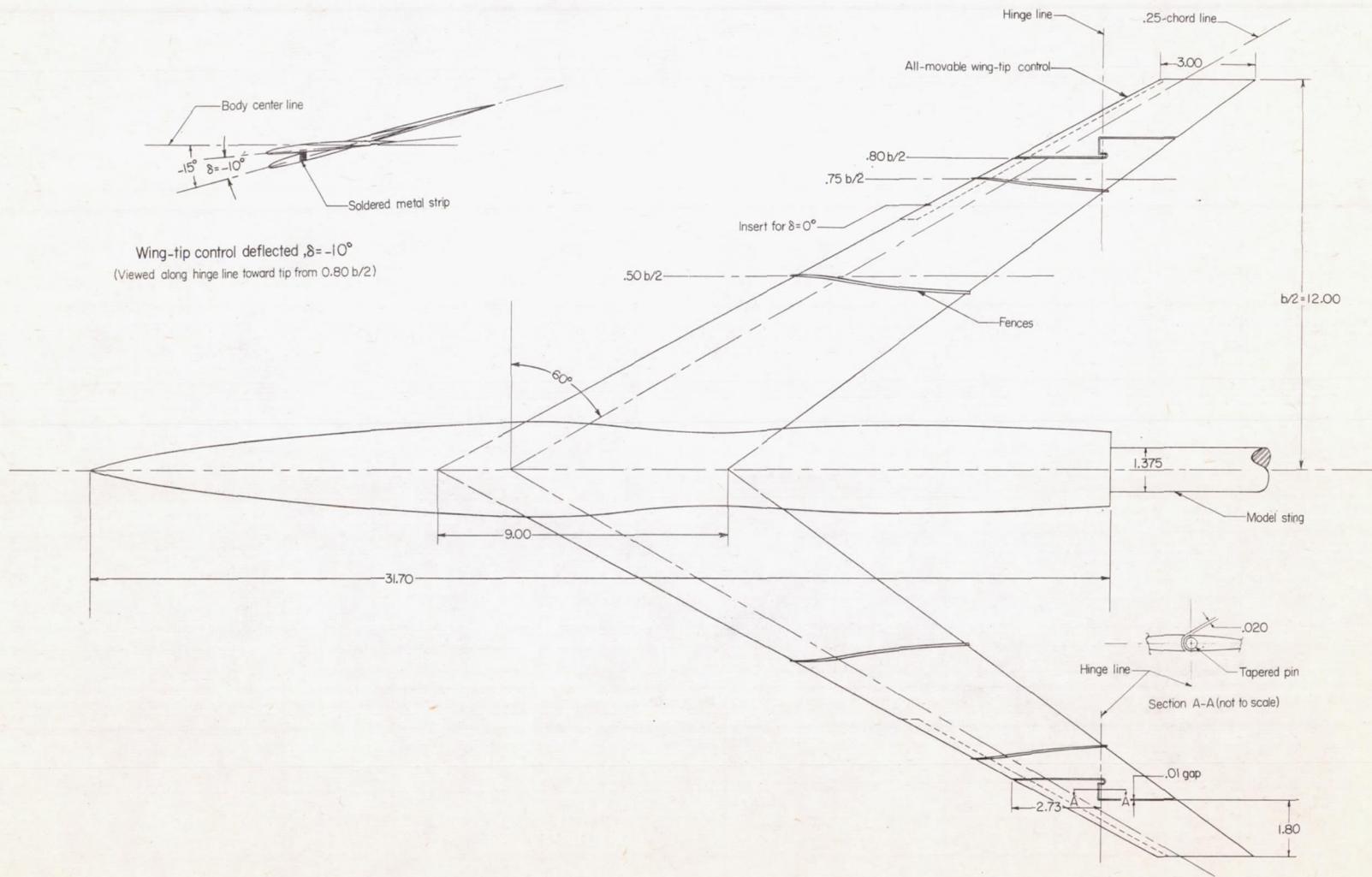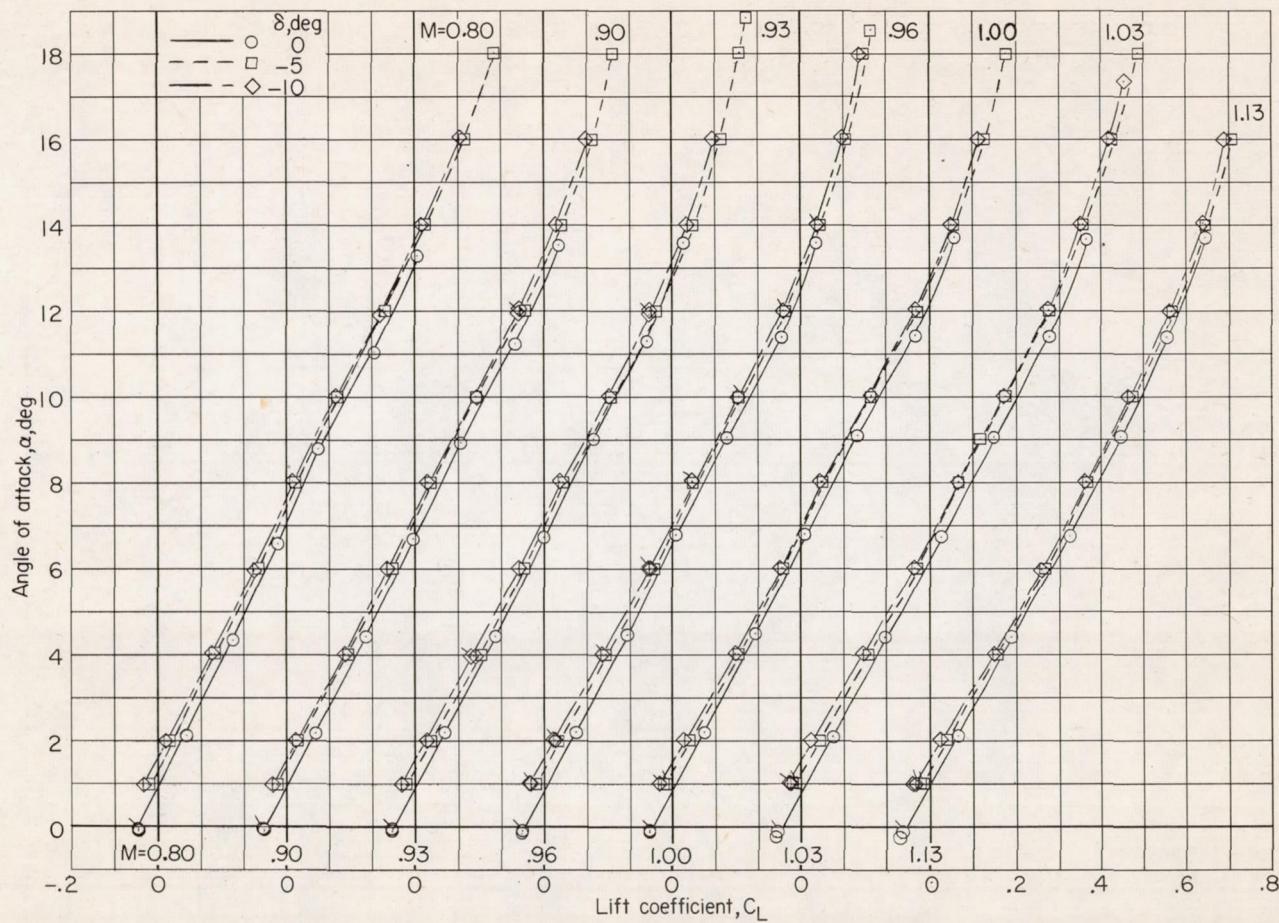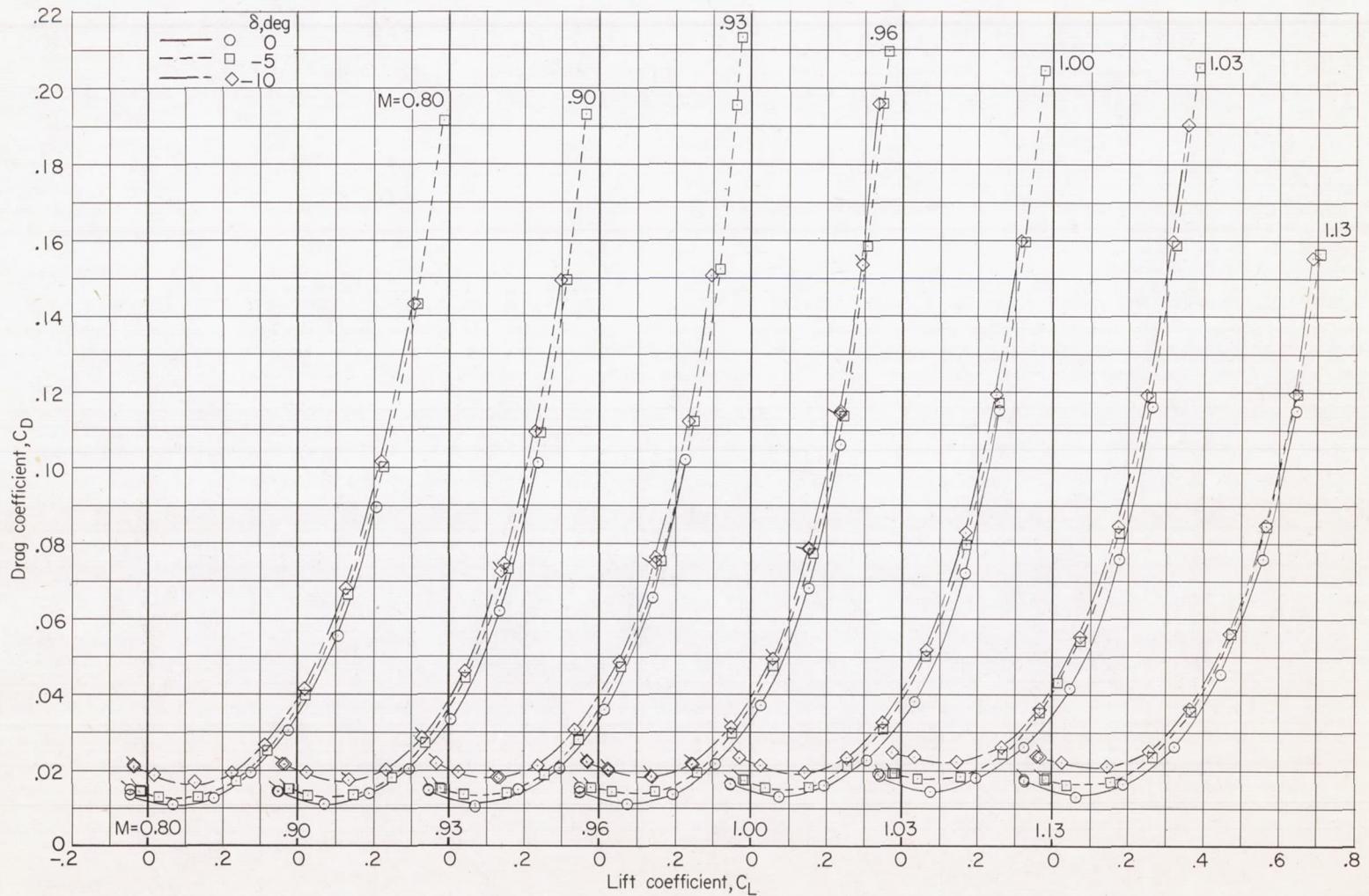semispan all-movable wing-tip control deflected -10°.

Figure 3.- Details of sweptback-wing—indented-body configuration with 20-percent-semispan all-movable wing-tip control. All dimensions are in inches.
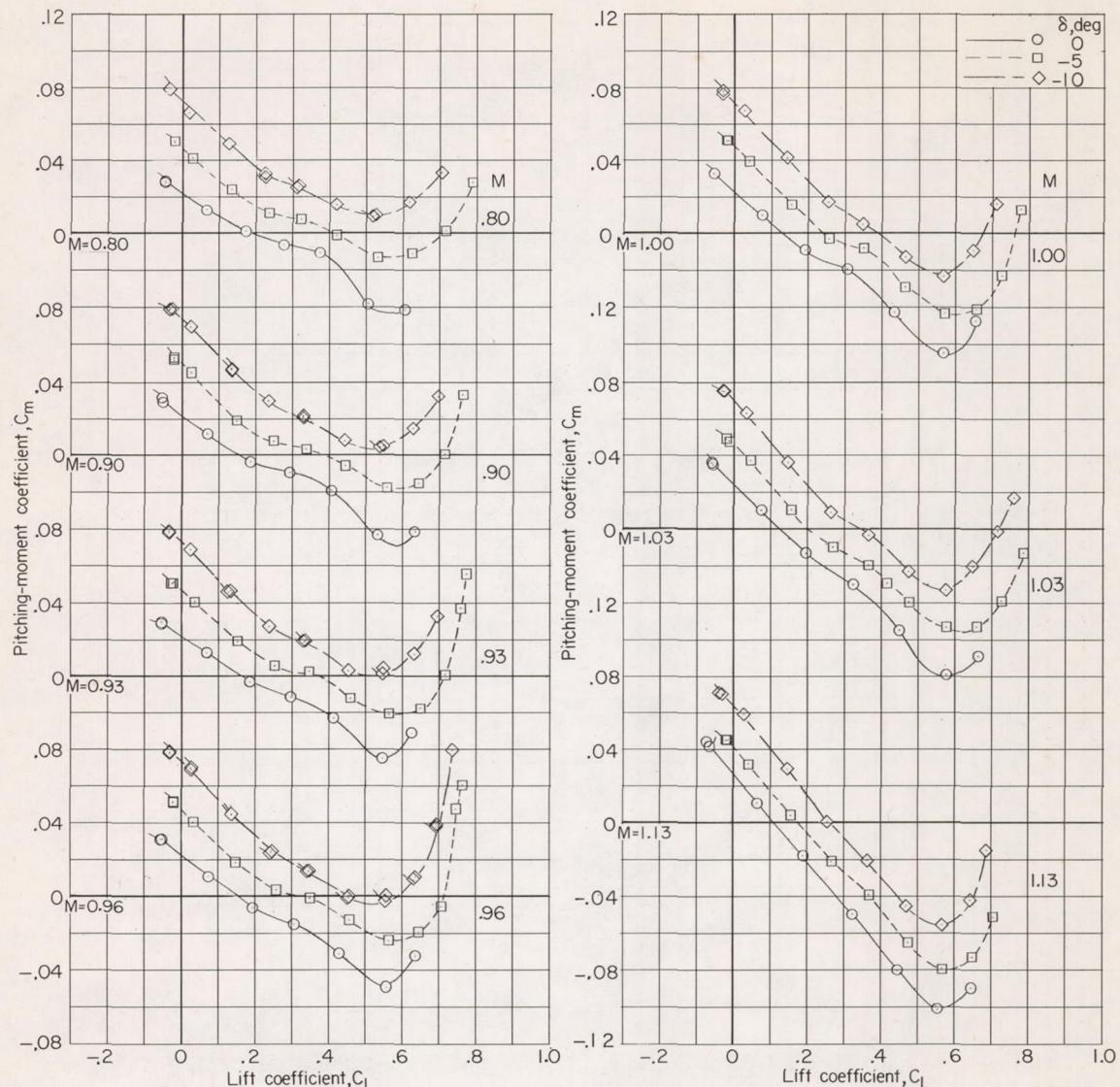
(a) Angle of attack.

Figure 4.- Variation with lift coefficient of aerodynamic characteristics of sweptback-wing—indented-body configuration with a 20-percent-semispan wing-tip control deflected 0°, -5°, and -10°. (Flagged symbols indicate check points.)

(b) Drag coefficient.

Figure 4.- Continued.

(c) Pitching-moment coefficient.

Figure 4.- Concluded.
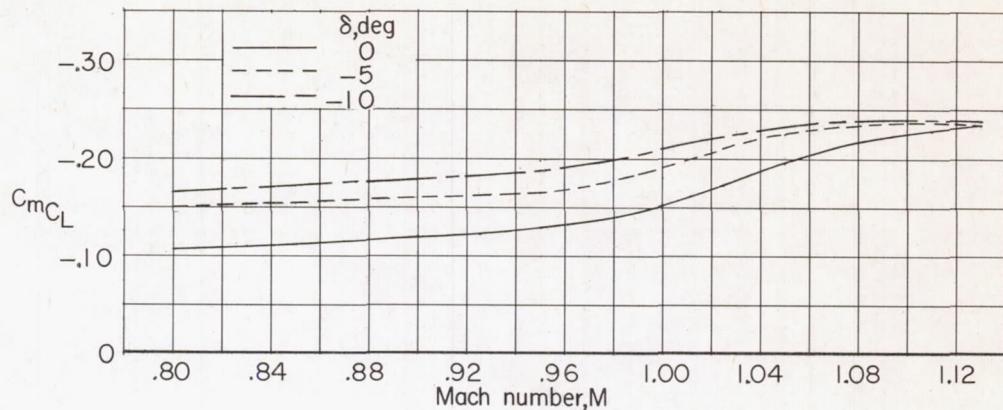
Figure 5.- Variation of $C_{m_{C_L}}$ with Mach number for sweptback-wing—indented-body configuration with 20-percent-semispan wing-tip control deflected $0°$, $-5°$, and $-10°$. $C_L = 0$ to 0.25.
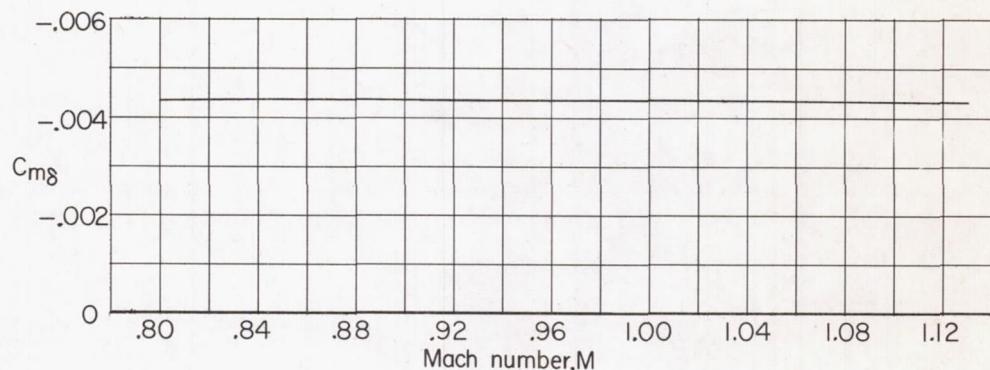

Figure 6.- Variation of C_{m_δ} with Mach number for sweptback-wing—indented-body configuration with 20-percent-semispan wing-tip control.
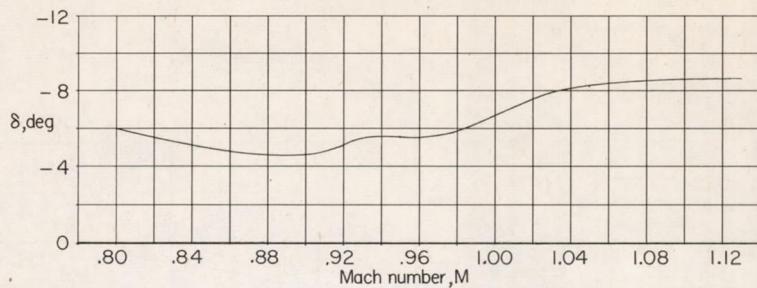
Figure 7.- Variation with Mach number of wing-tip control deflections
required for trim at altitude of 35,000 feet and wing loading of
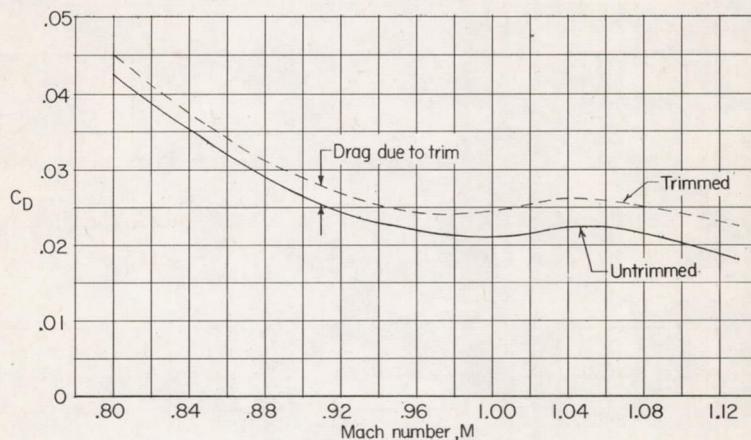100 pounds per square foot.

Figure 8.- Variation with Mach number of untrimmed and trimmed drag for
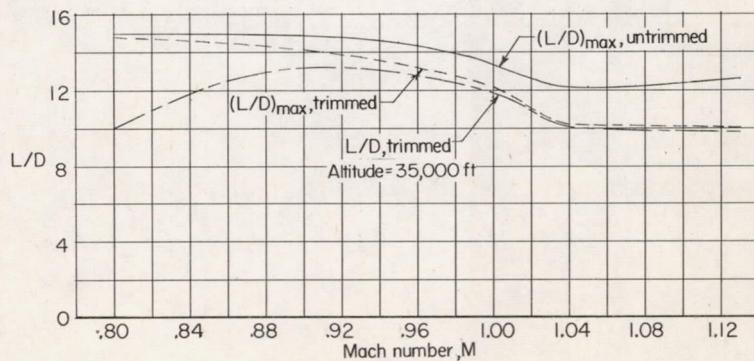altitude of 35,000 feet and wing loading of 100 pounds per square
foot.

Figure 9.- Variation with Mach number of maximum untrimmed and trimmed lift-
drag ratio, and trimmed lift-drag ratio for altitude of 35,000 feet and
wing loading of 100 pounds per square foot.